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TECHNICAL MEMORANDUMS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
1724 STREET, N.W.,
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USE OF HELIUM IN AIRSHIPS.

By G. Arturo Crocco.

From "Reale Accademia Nazionale dei Lincei," Volume XXXII,
Series 5, 1st sem., No. 2, Jan. 21, 1923.

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

TECHNICAL MEMORANDUM NO. 208.

USE OF HELIUM IN AIRSHIPS.*

By G. Arturo Crocco.

The helium problem may today be stated as follows: The census of the American wells shows a total output of this gas of 30,000 cubic meters per day, about a third of which can be readily extracted by plants costing about seventy million dollars. By dividing this expense by the average life of the wells, assumed as twenty years, and adding the cost of production, we obtain for compressed helium a minimum cost of about two dollars per cubic meter for a probable annual production of three million cubic meters.

Disregarding military uses, which do not depend on economical considerations, is it desirable, for commercial purposes, to substitute helium for hydrogen which costs only about one-fifteenth as much and is always available?

Let us, therefore, compute the cost of the annual consumption for one airship and, consequently, the total airship tonnage which can be maintained with the limited American supply of helium.

The gas consumption of an airship is due to: a) osmose; b) replenishing required to maintain a certain degree of purity; c) navigation.

* From "Reale Accademia Nazionale dei Lincei," Vol. XXXII, Series 5, 1st sem., No. 2, Jan. 21, 1923, pp. 64-67. Communication made at the session of June 3, 1922.

Of these three causes, the last is the most important in the present state of the science and art of airship navigation. Let us then estimate the most important losses in regular commercial traffic.

Navigation losses.- In fact, an airship not entirely full, which maintains itself in constant equilibrium with the surrounding air, exerts a constant lifting power at any altitude and is therefore lightened in its path by an amount equal to the weight of the fuel consumed. Theoretically, it is therefore compelled to lose during the voyage just enough gas to offset the fuel consumed, or about a cubic meter of gas for every kilogram of fuel.

In practice, this law is affected by various conditions, both foreseeable and unforeseeable, such as: disturbance of equilibrium in taking off and in landing; temperature variations between the gas and the atmosphere, due to variations in the heat received from the sun; foreign deposits on the envelope; dynamic sustentation; so that a wise pilot, by choosing suitable conditions and maneuvers and knowing how to take advantage of meteorological conditions, can make exceptional voyages with scarcely any loss of gas. Such personal ability, however, does not affect the general application of the law, especially in regular commercial service, with time schedules.

If the weight of the materials consumed is calculated for long voyages and intensive traffic (say 4000 hours a year), it is found that, on the basis of one cubic meter of gas per kilogram,

an airship of 100,000 cu.m. gas capacity, equipped with engines producing a total of about 3600 HP and navigating at one-half force with a mean hourly consumption of 500 kg., would consume in a year 2,000,000 cu.m. of gas, or twenty times its own volume, so that nearly the whole production of American helium would be required to supply a single airship and its cost would be prohibitive.

Even with hydrogen, the consumption would still be excessive, so that no practical use can be made of airships, unless the constant gas replenishment is eliminated by the complete compensation of the materials consumed in navigating.

This problem of compensation may be said to be solved in principle for most cases probable in practice, as I shall set forth in a later article, in which the most serious of the three causes, necessitating the replenishment of the gas in an airship, is shown to be capable of complete elimination.

There remain the other two, which we will proceed to examine.

a) Osmose.-- Although we do not yet have complete data on the loss of helium by osmose through balloon fabrics, comparative experiments have shown it to be a little more than half that of hydrogen. Experiments made at the Aeronautic Institute of Rome (Gallo, "L'elio in Aeronautica," Rendiconti dell'Istituto Aeronautico, February 1, 1921), on Italian rubberized fabrics with a weight of rubber between 80 and 160 g. per sq.m., gave, at ordinary temperatures, a mean loss of approximately 520/p liters in 24 hours, similar experiments with hydrogen showing a loss of 1000/p.

Previous American experiments (N.A.C.A., 1915, Report No.6), on fabrics with varying weights of rubber, seem to indicate that permeability is not inversely proportional to the thickness of the layer, i.e. to the weight of the rubber p. They also show that permeability increases rapidly with rising temperature. On the other hand, they demonstrate the possibility of greatly reducing the permeability, even at high temperatures, by the use of special dopes.

Hence it would not seem to be an exaggeration to assume a loss of three liters per square meter in 24 hours, for an airship of the size of the one under consideration, on the supposition that the impermeability of the fabric will yet be much improved.

According to these figures, the above-mentioned airship, with a surface area of 18000 sq.m., would lose annually by osmose, 19,440 cu.m. of gas, or less than 20% of its volume. For larger volumes the loss would be relatively smaller, not only on account of the proportionally smaller surface area (Reale Accademia Nazionale dei Lincei 1922, No.10), but also on account of the heavier fabric.

b) Replacing gas adulterated by air, in order to maintain a sufficient degree of purity.- At present, the replenishment of the gas, necessitated by losses due to consumption of materials in navigating, is sufficient to maintain the required degree of purity in the envelope. If, however, this replenishment should be eliminated, the replacing of a portion of the gas would become a daily

necessity of greater importance than the loss due to osmose. In fact, for every cubic meter of helium lost by osmose, about 400 liters of air would enter the balloon. This air has to be removed in order to maintain a constant degree of purity. If α represents this mean degree of purity and ω the % of helium lost by osmose per unit time, in order to remove an equal quantity of air, 0.4ω , it would be necessary to replace, per unit time, a percentage volume of impure helium equal to $\frac{0.4 \omega}{1 - \alpha}$ with an equal amount of pure helium. Thus, in order to maintain, for example, a purity (α) of 96%, with an annual loss of 20% by osmose, an annual replacement equal to double the volume of the gas capacity of the airship would be necessary.

Even this noteworthy cause of gas consumption may be entirely eliminated by purifying the helium, that is, by removing the air, which adulterates it, by refrigeration and consequent liquefaction. In America, purifying plants, mounted on railway cars, are already in use. For commercial navigation, however, it would only be necessary to have stationary purifying plants of limited hourly capacity, supplemented by a double replenishing tank. The replacement could then be made periodically with helium already purified, while the impure gas, removed at the same time, could be subsequently purified.

Summarizing the three causes for replenishing helium, namely, losses from navigating, replacing and osmose, which stand to each other in the proportions of 100, 10 and 1, only the loss by

osmose is impossible of elimination, requiring a mean annual replacement of about 20%. This has two fundamental results.

1. That, with the necessity of replenishing reduced to this single cause, the available American helium would be capable of supplying not simply one, but 150 airships of the mean gas capacity indicated, or a total tonnage of fifteen million cubic meters.

2. That the cost of helium would then be sufficiently reduced for commercial purposes, because, in addition to the amount required for the original inflation, there would be required an annual replacement of only 20%, or, in other words, it would take five years to exhaust the original supply.

Helium would then be no longer a consumable substance, but a building material, the cost of which would be ammortizable in five years. Hence its substitution for hydrogen for commercial purposes would become practicable and practical.

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